

AD-A099 438

AEROSPACE CORP EL SEGUNDO CA SPACE SCIENCES LAB

F/8 9/2

AUGUST 1979 LSI STATIC MEMORY TESTS.(U)

MAY 81 W A KOLASINSKI

F04701-80-C-0081

NL

UNCLASSIFIED

TR-0081(6960-05)-16

SD-TR-81-36

1-1
2-1

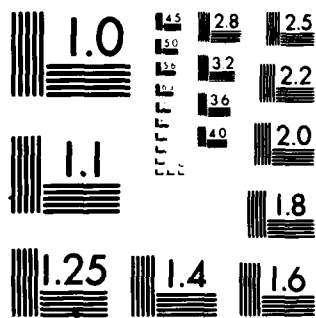
END

DATE

FILMED

7-81

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LEVEL II

12
13

AD A099438

August 1979 LSI Static Memory Tests

W. A. KOLASINSKI and J. B. BLAKE
Space Sciences Laboratory
Laboratory Operations
The Aerospace Corporation
El Segundo, Calif. 90245

1 May 1981

DTIC
ELECTE
S MAY 28 1981
A

**APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED**

Prepared for
SPACE DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles, Air Force Station
P.O. Box 92960, Worldway Postal Center
Los Angeles, Calif. 90009

81 5 28 013

DTIC FILE COPY

1 -

This report was submitted by The Aerospace Corporation, El Segundo, CA 90245, under Contract No. F04701-80-C-0081 with the Space Division, Deputy for Technology, P. O. Box 92960, Worldway Postal Center, Los Angeles, CA 90009. It was reviewed and approved for The Aerospace Corporation by G. A. Paulikas, Director, Space Sciences Laboratory. Maj John A. Criscuolo, SD/YLXT, was the project officer for the Mission Oriented Investigation and Experimentation Program.

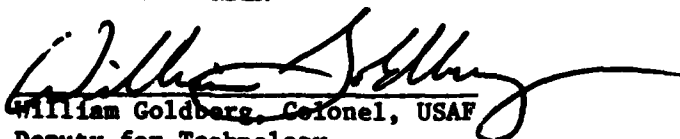
This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.


John A. Criscuolo, Major, USAF
Project Officer


Florian P. Meinhardt, Lt Col, USAF
Director of Advanced Space Development

FOR THE COMMANDER


William Goldberg, Colonel, USAF
Deputy for Technology

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

1. REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER (18) SD-TR-81-36	2. GOVT ACCESSION NO. AD-A099438	3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) (1) AUGUST 1979 LSI STATIC MEMORY TESTS.		5. TYPE OF REPORT & PERIOD COVERED (9) Technical report	
7. AUTHOR(s) (10) Wojciech A. Kolasinski		6. PERFORMING ORG. REPORT NUMBER (14) TR-0081(6960-05)-16	
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Aerospace Corporation El Segundo, CA 90245		8. CONTRACT OR GRANT NUMBER(s) (15) F04701-80-C-0081	
11. CONTROLLING OFFICE NAME AND ADDRESS Space Division Air Force Systems Command Los Angeles Air Force Station Los Angeles, CA 90009		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 01-1-1-1	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE (12) 1 May 1981	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		13. NUMBER OF PAGES 13	
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		15. SECURITY CLASS. (of this report) Unclassified	
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Cosmic Rays RAM Heavy Ion Soft Errors Iron-Group Nuclei Threshold Ionization Latchup			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Several types of LSI static RAM's have been tested with heavy ions from the Lawrence Berkeley Laboratory 88C Cyclotron. Sufficient data were obtained to make the estimate that the latchup probability due to cosmic rays in space is approximately 0.02 per chip per year, for the MM54C929 RAM. The tests also showed that MWS5501 RAM's are essentially immune to cosmic-ray induced soft errors and latchup. Furthermore, it was found that the commercial version of the HM6508 is susceptible to both latchup and soft errors, while the various rad-hard			

DD FORM 1473
(FACSIMILE)

407512

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

19. KEY WORDS (Continued)

(approx. 1×10 to the minus 7th power)

20. ABSTRACT (Continued)

versions of the same device are immune to cosmic-ray induced latchup and relatively hard against soft errors (5.1×10^{-7} per bit per day).

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Avail and/or	
Dist	Special
A	

B

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

August 1979 LSI Static Memory Tests

1. Test Objectives

There were two main objectives in the performance of these tests. The first was to establish the degree of susceptibility, if any, of various devices to heavy-ion induced latchup. In addition, the second objective was to obtain data needed to make a reasonable prediction of soft bit-error rates in the various devices, caused by cosmic rays in space. While time available for the tests did not permit a completely exhaustive study of the various devices, sufficient data were obtained to fulfill the first objective completely and to answer in large measure the questions implied by the second objective. Top priority in the test sequence was given to two versions of Harris 6508 RAM and the MM54C929 devices in the flat-pack version. Various other devices, listed in Table 1 were tested on a time-available basis.

2. Test Plan and Implementation

Detailed descriptions of the apparatus and test procedures have been given by Kolasinski et al. Table 1 contains a list of the part types tested together with a summary of their properties and types of tests performed.

The test plan was based on the a priori knowledge that a beam of 150 MeV krypton ions would cause some of the parts to latch and produce soft errors in most, if not all, of the devices. It was also assumed that to observe latchup and soft-errors, ionization charge in excess of a minimum amount must be produced within the sensitive volume of the device. Since the ionizing power of 150 MeV krypton is approximately 1.4 times higher than the maximum ionizing power of any cosmic rays encountered with

significant frequency in space, it was felt that the 150 MeV krypton beam represented a conservative upper bound for the severity of the effect of cosmic rays on the test components. Consequently, the plan called for an initial set of exposures to the krypton beam, with elimination from further testing of parts which either showed no soft errors and no latchup upon exposure at any angle to the beam, or whose threshold charge for the two effects could be deduced from the krypton runs by varying the exposure angle. Uneliminated parts would then be tested with available beams of argon and neon in a similar manner. Table 2 lists some of the relevant properties of the beams used in the testing.

Two sample boards, labelled Board V and Board VI, were designed and built to hold the test samples in the vacuum test chamber. Board V was for dual-inline plug-in parts with six positions reserved for HM6508's or electrically compatible parts and two positions used for HM6504's. On Board VI there were eight positions for soldering in the flat-pack version of MM54C929's or their equivalent. The various test memories were loaded and interrogated by a CD1802 microprocessor-based computer.

3. Results and Discussion

Table 3 is a summary of the test results. Due to lack of time, the devices on Board V could only be tested with krypton. Board VI was first exposed to krypton, then neon and finally to argon, in order to establish a lower bound for the ionizing power of particles capable of inducing latchup in the MM54C929 memories.

Five different groups of Harris 6508 RAM's were tested. These were obtained from the several programs which had requested test data.

Unfortunately, the traceability of some of these parts was somewhat dubious, so for purposes of the tests reported herein, labels based on priority in the test sequence, or on the source of the parts, have been appended as follows: P (prime interest), Q (questionable), R (RCA), S (Sandia) and T (tested by Rockwell). These letters appear in parentheses after the part number shown in Table 3. The parts which latch readily and presumably have large susceptibility to bit errors (Q and R in Table 3) have been identified as the standard commercial HM6508 RAM's. The other three groups (P, S and T in Table 3) represent rad-hard versions of HM6508 RAM's. Clearly they are also superior as far as performance in the presence of cosmic rays is concerned. Using estimates made by Pickell and Blandford, the expected bit-error rate in space for these parts should not exceed 1×10^{-7} errors per bit per day. Since the observed error-threshold energy appears close to that of the CD4061 RAM and since Sivo et al. predict an error rate of approximately 1×10^{-8} errors per bit per day for that memory, the HM6508 (P) error rate of 1×10^{-7} errors per bit per day can be regarded as a conservative estimate.

Apart from the MWS5501 SOS RAM which appears error-proof and the HM6508's discussed above, the value of the rest of the parts tested is questionable where space applications are concerned. The IM6508 while latchup proof, will show an error rate in space at least an order of magnitude higher than the above "good" 6508's. As far as the rest of the parts, they latch and are error-prone, so the risks of their use in space programs would appear rather high.

Time did not permit to obtain all the data needed to predict the expected latchup frequency in space. In case of the MM54C929 parts,

beams of neon (0.08 pC/ μ m ionization rate) and argon (0.15 pC/ μ M) did not cause latchup, whereas krypton, with ionization rate of 0.4 pC per micrometer did. There is reason to believe that the 0.15 pC per micrometer rate is close to the device threshold for latchup, since in previous tests argon had produced latchup in devices of this type. Using this value for threshold ionization rate, one can easily estimate the probability of MM54C929 latchup in space by assuming only iron-group nuclei can cause the effect. The flux of iron-group nuclei is approximately 1×10^{-3} particles/(m^2 sr MeV sec) at energies in the hundreds of MeV/nucleon. Actually the above value corresponds to the peak in the spectrum. By assuming the value to be constant at energies above 100 MeV one makes an error in the conservative direction. It turns out that only iron nuclei with energies below 8 MeV/nucleon are able to generate sufficient ionization charge, while in order to penetrate shielding thickness equivalent to 1 gm/cm² of aluminum, they must have energies above 100 MeV/nucleon. The shielding thus acts like a filter, allowing particles in a very narrow energy window to produce latchup. This window is approximately 3 MeV wide, so the flux of particles capable of producing latchup is

$$1 \times 10^{-3} \times 10^{-4} \times 4\pi \times 3 \times 86,400 \\ = 0.3 \text{ particles}/(\text{day cm}^2)$$

where it was assumed that all ions with energy below 15 MeV/nucleon will be capable of producing latchup, and that the cosmic-ray intensity is uniform over a solid angle of 4π . In the interest of conservatism, let

it be further assumed that these particles encounter the same area for latchup, regardless of the angle of incidence. Under those conditions, with the measured latchup cross-section of 2×10^{-4} cm, multiplied by the flux of 0.3 particles/(cm² day) gives the latchup rate of 6×10^{-5} latchups/(chip day) or 0.02 latchups/(chip year). In low-altitude polar orbits the daily flux encountered by a spacecraft is approximately 1/3 of that quoted above, so that the above latchup frequency should be reduced by the same factor.

4. Summary and Conclusions

In the tests described above, several types of electrically equivalent parts (Table 1) have been tested for susceptibility to latchup and soft bit errors. One of these, the MWS5501 appears completely immune to malfunctions of this type caused by heavy cosmic rays in space. The other RAMs tested, can be grouped into three classes as follows:

1. Highly immune to latchup and soft bit errors: HM6508 (P)
HM6508 (S), HM6508 (T)
2. Highly immune to latchup, susceptible to soft errors: IM6508
3. Susceptible to errors and latchup: HM6508 (Q), HM6508 (R),
MM54C929 and HM6504

Except for the MM54C929, time did not permit measurement of the degree of susceptibility of parts in category 2 and 3 above.

Extensive tests were performed on MM54C929 RAMs relating to both latchup and error susceptibility thresholds. The parts fit in category 3, with predicted latchup rates quoted in Section 3. Prediction of bit error rate in space requires knowledge of device parameters which presumably could be supplied by the manufacturer. At the time of this test effort, the above information was not available.

TABLE 1 Parts Tested in August 1979

Part #	Technology	Organization	Beam Types
MM54C929	CMOS/Si gate	1024 x 1	Kr, Ar, Ne
HM6508	CMOS/Si gate	1024 x 1	Kr
IM 6508	?	1024 x 1	Kr
HM6504	CMOS/Si gate	4096 x 1	Kr
MWS5501	SOS	1024 x 1	Kr

TABLE 2 Test Beam Properties

Particle Type	Energy (MeV)	Rate of Energy Loss in Si (MeV cm ² /gm)	Ionization Rate in Si (pC/μM)
Kr	150	40,000	0.41
Fe*	112	29,000	0.30
Ar	172	14,700	0.15
Ne	43	7800	0.08

*Quoted for comparison only--no test beam available

TABLE 3 Summary of Test Results

Part #	Beam	Response	Latch X-sect (cm ²)	Bit-error X-sect (cm ²)
MWS5501	Kr	None	0	0
HM6508 (P)	Kr	Errors	0	6.5×10^{-4}
HM6508 (Q)	Kr	Errors/latch	1.6×10^{-4}	1×10^{-2}
HM6508 (R)	Kr	Latch; errors?	$> 2 \times 10^{-5}$?
HM6508 (S)	Kr	Errors	0	1.3×10^{-3}
HM 6508 (T)	Kr	Errors	0	7.7×10^{-4}
IM6508	Kr	Errors	0	3.4×10^{-3}
HM6504	Kr	Errors; latch	1×10^{-3}	3.1×10^{-2}
MM54C929 (A) *	Kr, Ar, Ne	Errors; latch	2.2×10^{-4}	5.4×10^{-3}
MM54C929 (B) *	Kr, Ar, Ne	Errors; latch	6×10^{-4}	7×10^{-3}
MM54C929 (C) *	Kr, Ar, Ne	Errors; latch	4×10^{-4}	7×10^{-3}

* A - standard part
 B - irradiated with 10^{13} neutrons/cm²
 C - irradiated with 10^{14} neutrons/cm²

References

- W. A. Kolasinski, J. B. Blake, J. K. Anthony, W. E. Price and E. C. Smith, "Simulation of Cosmic-Ray Induced Soft Errors and Latchup in Integrated-Circuit Computer Memories," SSL-79(4470-02)-1, The Aerospace Corporation, August 1979.
- J. C. Pickel and J. T. Blandford, private communication.
- L. L. Sivo, M. Brettschneider, W. Price, and P. Pentecost, "Cosmic Ray Induced Soft Errors in Static MOS Memory Cells," 1978 IEEE Annual Conference on Nuclear and Space Radiation Effects, Santa Cruz, CA, July 17-20, 1979.

LABORATORY OPERATIONS

The Laboratory Operations of The Aerospace Corporation is conducting experimental and theoretical investigations necessary for the evaluation and application of scientific advances to new military concepts and systems. Versatility and flexibility have been developed to a high degree by the laboratory personnel in dealing with the many problems encountered in the nation's rapidly developing space and missile systems. Expertise in the latest scientific developments is vital to the accomplishment of tasks related to these problems. The laboratories that contribute to this research are:

Aerophysics Laboratory: Launch and reentry aerodynamics, heat transfer, reentry physics, chemical kinetics, structural mechanics, flight dynamics, atmospheric pollution, and high-power gas lasers.

Chemistry and Physics Laboratory: Atmospheric reactions and atmospheric optics, chemical reactions in polluted atmospheres, chemical reactions of excited species in rocket plumes, chemical thermodynamics, plasma and laser-induced reactions, laser chemistry, propulsion chemistry, space vacuum and radiation effects on materials, lubrication and surface phenomena, photosensitive materials and sensors, high precision laser ranging, and the application of physics and chemistry to problems of law enforcement and biomedicine.

Electronics Research Laboratory: Electromagnetic theory, devices, and propagation phenomena, including plasma electromagnetics; quantum electronics, lasers, and electro-optics; communication sciences, applied electronics, semiconducting, superconducting, and crystal device physics, optical and acoustical imaging; atmospheric pollution; millimeter wave and far-infrared technology.

Materials Sciences Laboratory: Development of new materials; metal matrix composites and new forms of carbon; test and evaluation of graphite and ceramics in reentry; spacecraft materials and electronic components in nuclear weapons environment; application of fracture mechanics to stress corrosion and fatigue-induced fractures in structural metals.

Space Sciences Laboratory: Atmospheric and ionospheric physics, radiation from the atmosphere, density and composition of the atmosphere, aurorae and airglow; magnetospheric physics, cosmic rays, generation and propagation of plasma waves in the magnetosphere; solar physics, studies of solar magnetic fields; space astronomy, x-ray astronomy; the effects of nuclear explosions, magnetic storms, and solar activity on the earth's atmosphere, ionosphere, and magnetosphere; the effects of optical, electromagnetic, and particulate radiations in space on space systems.

THE AEROSPACE CORPORATION
El Segundo, California

